Effects of Neglecting Polarization on the MODIS Aerosol Retrieval Over Land

Robert C. Levy, Lorraine A. Remer, and Yoram J. Kaufman

***Abstract*—Reflectance measurements in the visible and infrared wavelengths, from the Moderate Resolution Imaging Spectroradiometer (MODIS), are used to derive aerosol optical thicknesses (AOTs) and aerosol properties over ocean and land surfaces, separately. Both algorithms employ radiative transfer (RT) code to create lookup tables, simulating the top-of-atmosphere (TOA) reflectance measured by the satellite. Whereas the algorithm over ocean uses a vector RT code that includes the effects of atmospheric polarization, the algorithm over land assumes scalar RT, thus neglecting polarization effects. In the red (0.66 μm) and infrared (2.12 μm) MODIS channels, scattering by molecules (Rayleigh scattering) is minimal. In these bands, the use of a scalar RT code is of sufficient accuracy to model TOA reflectance. However, in the blue (0.47 μm), the presence of larger Rayleigh scattering (optical thickness approaching 0.2) results in nonnegligible polarization. The absolute difference between vector- and scalar-calculated TOA reflectance, even in the presence of depolarizing aerosols, is large enough to lead to substantial errors in retrieved AOT. Using RT code that allows for both vector and scalar calculations, we examine the reflectance differences at the TOA, assuming discrete loadings of continental-type aerosol. We find that the differences in blue channel TOA reflectance (vector–scalar) may be greater than 0.01 such that errors in derived AOT may be greater than 0.1. Errors may be positive or negative, depending on the specific geometry, and tend to cancel out when averages over a large enough sample of satellite geometry. Thus, the neglect of polarization introduces little error into global and long-term averages, yet can produce very large errors on smaller scales and individual retrievals. As a result of this study, a future version of aerosol retrieval from MODIS over land will include polarization within the atmosphere.**

***Index Terms*—Aerosol, land, Moderate Imaging Spectroradiometer (MODIS), polarization, radiative transfer.**

I. Introduction

Atmospheric aerosols are intimately linked to earth's climate system [1], hydrological cycle [2], and to the well being of earth's inhabitants [3]. However, aerosols are difficult to study on a global scale because they are inhomogeneous on all temporal, horizontal, and vertical scales. Satellite measurements are increasingly important to the study of aerosols in earth's system [4], [5], because they can view large parts of the globe within a short time span. Passive sensors, such as the Moderate Imaging Spectroradiometer (MODIS) [6], flying aboard Terra [7] and Aqua [8], measure reflected radiation at the top of the atmosphere (TOA) and do not disturb the ambient aerosol composition. As compared to previous satellite sensors used for (but not designed for) aerosol retrieval (such as the Advanced Very High Resolution Radiometer (AVHRR; e.g., [9]), MODIS has a much wider spectral range (0.412–15 μm), finer spatial resolution (250–1000 m), and is calibrated to a much higher accuracy [10]. Thus, MODIS is a premier instrument for estimating the spectral aerosol optical thickness (AOT), leading to estimates of aerosol size parameters.

MODIS retrieves clear sky (noncloudy) aerosol optical thickness (AOT) over ocean and land, using two separate algorithms [11]–[14]. The ocean algorithm retrieves AOT in seven wavelength bands, centered near 0.47, 0.55, 0.66, 0.87, 1.24, 1.64, and 2.12 μm, by inverting reflectance in six of the seven bands (0.47 μm is contaminated by variable ocean surface reflectance and is not used in the retrieval). The land algorithm derives AOT in two bands (0.47 and 0.66 μm), by using reflectance in three bands (0.47, 0.66, and 2.12 μm), and then interpolates to find AOT at 0.55 μm. Therefore, both algorithms report the AOT at 0.55 μm and an estimate of the spectral dependence of the AOT. Both algorithms make use of lookup tables (LUTs), wherein TOA spectral reflectance (in percent) is simulated by radiative transfer (RT) calculations. Included within the RT are assumptions about the surface reflectance, molecular scattering, and aerosol scattering/absorption (functions of assumed aerosol chemical and size parameters). For each cloud-screened MODIS pixel of suitable quality [14], the retrieval algorithm attempts to mimic the observed spectral reflectance with values from the LUT. Minimum total differences between the two spectral quantities lead to solutions of spectral AOT. Over ocean, the minimization is applied to the six wavelengths simultaneously, whereas over land, the minimization is applied to the 0.47- and 0.66-μm channels independently.

Ocean and land AOTs each have theoretical expected error bars [11], [12], which have been subsequently "validated" [14]–[17] by comparing to ground based sunphotometers, such as those of the AERosol Robotic NETwork (AERONET) [18]. Over nondusty ocean sites, global MODIS/AERONET AOT regression lines have slopes near one, offsets near zero, and correlation coefficients of 0.9 and above. Over land sites, the global MODIS/AERONET regression has an offset about 0.1, slope about 0.8, and correlation coefficients of about 0.6.

Why is the MODIS/AERONET comparison so much poorer over land surfaces? The fundamental strategy for each algorithm

Manuscript received May 20, 2004; revised August 30, 2004. This work was supported by the National Aeronautics and Space Administration's Earth Sciences as part of the MODIS Project.

R. C. Levy is with Science Systems and Applications, Inc., Lanham, MD 20771 USA, the Laboratory for Atmospheres, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD 20771 USA and also with the Department of Meteorology, University of Maryland, College Park, MD 20742 USA (e-mail: levy@ climate.gsfc.nasa.gov).

L. A. Remer and Y. J. Kaufman are with the Laboratory for Atmospheres, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, MD 20771 USA (e-mail: remer@climate.gsfc.nasa.gov; kaufman@climate.gsfc.nasa.gov).

Digital Object Identifier 10.1109/TGRS.2004.837336